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Unified Information Access in Product Creation with an Integrated Control Desk

Kevin Wrasse¹, Holger Diener², Haygazun Hayka¹, Rainer Stark^{1,3}

¹ Fraunhofer Institute for Production Systems and Design Technology (IPK), Berlin, Germany

² Fraunhofer Institute for Computer Graphics Research IGD, Rostock, Germany

³ Technical University Berlin, Germany

kevin.robert.wrasse@ipk.fraunhofer.de

Abstract. Customers demand for individualized products leads to a large variety of different products in small series and single-unit production. A high flexibility pressure in product creation is one result of this trend. In order to counteract the pressure, the information steadily increasing by Industry 4.0 must be made available at the workplace. Additionally, a better exchange of information between product development, production planning and production is necessary. The improvement of individual systems, like CAD, PDM, ERP and MES, can only achieve this to a limited extent. Since they mostly use systems from different manufacturers, the necessary deeper integration of information is only feasible for SMEs to a limited extent. The presented control desk helps to ensure a more flexible product creation as well as information exchange. It captures information from different IT systems in the production process and presents them integrated, task-oriented and oriented to the user's mental model, e.g. information of the production combined with the 3D model of product parts, or information about product development on the 3D model of the production. The solution is a digital 3D model of the manufacturing environment, which is enriched by billboards for a quick information overview and web service windows to access detailed MES and PDM information. By this, the level of abstraction can be reduced and reacts to changed requirements in the short term, making informed decisions. The interaction with the control stands utilizes the touch skills of mobile and fixed systems such as smartphones, tablets and multitouch tables.

1. Introduction

The evolution in manufacturing under the term "Industry 4.0" aims at further automation by so-called cyber-physical systems in order to make production processes more efficient. This leads to an increasing investment of companies in specialized IT systems for digital product development and production. Nevertheless, there are always areas of product creation in which human beings play an important role. Complex heterogeneous IT systems can lead to a high cognitive load and ultimately to errors. An integrating control desk for customized information supply was developed to decrease this problem. Previous work for information supply was the project T3PAD by the Technical University Braunschweig in which a multi-table for factory planning was developed. This provided only a 2D plan view of the factory as well as various libraries with virtual objects. Again, no further integration of information from other areas was planned. [1] The SCA Multitouch Prototype from ABB and the Interactive Institute Umeå provide up-to-date production figures based on a multitouch 3D model.



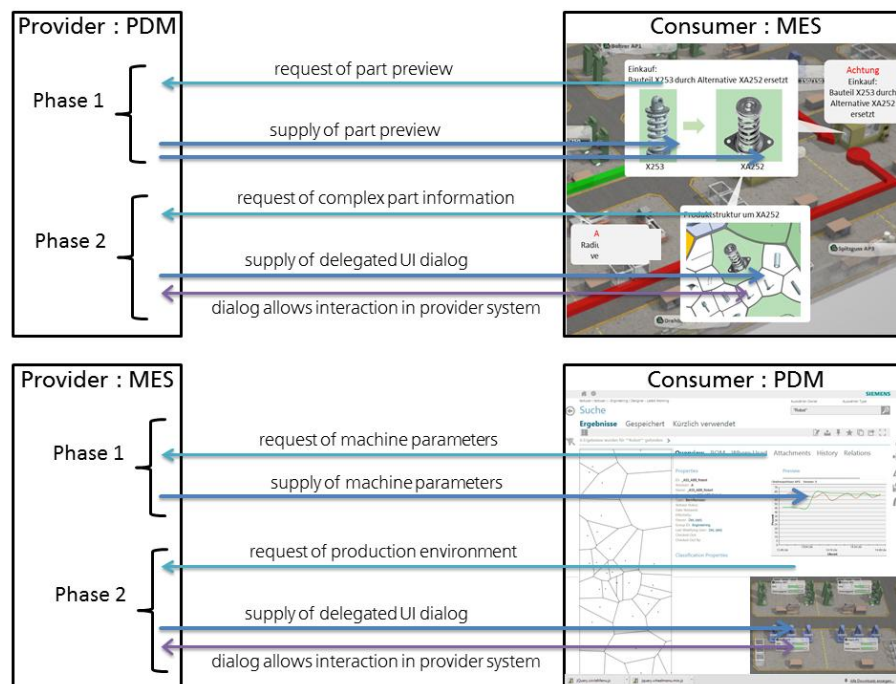


Figure 1. Information flow in control desk demonstrator

However, integrating access to other IT systems is also missing here. The system is only a prototype and is not available as a product.[2] The company iconics distributes Genesis64 for the visualization of company data in 3D models. The software combines operational data of the company but does not support product planning and does not allow any exchange of information.[3] Each of the described systems are only taking limited aspects of product development into account. The need for a cross-sectoral exchange of information is not covered. In product creation, the processes of product development and production have been largely separated from one another. This is also reflected in the software tools for both processes. An exception here are the CAD-CAM process chains, in which the results of the product development are transmitted directly to the production. However, in most cases only unidirectional information flow is possible.[4] This is countered by the ever-growing demand for information, as well as the demand for increasingly individualized products. This is accelerated both by the technological development of sensor technology and data processing in production, as well as the increasing use of cyber-physical systems. Despite these large quantities of information and information requirements, there is a lack of mutual availability of information between the processes of product development and production [5]. For example, the production planner does not receive any feedback on how and whether his developed models have been implemented. Producing companies need fast and easy access to all relevant product creation information. The new work area “control desks for the product creation“ addresses this demand. The information from the different systems is integrated into a control desk application, which allows a number of applications (as individual workplace and for cooperative work) through expansion modules.

2. Development of use-cases

Four applications were developed and further developed during the course of the project.

2.1. Information of production for product development and production planning

The application case shows how information from production can flow into product development. During the development of a new product, feedback from the production of the previous model, as well as user feedback are incorporated and have influence on the design of the product. Employees from product development and production planning compare the new product structure

with the old one and then analyze the influence of the new structure on the production. In doing so, they access information from previous production processes. Important in this application is the possibility to generate the flow of information from production back into product development and production planning. This is shown in the lower diagram of figure 1. An integrated visualization between product development and production can provide the necessary attention for problems.

2.2. Information of product development for manufacturing

If parts of the product have to be replaced during production or if the production process changed, the production personnel needs product information on the new components. Instead of obtaining the entire product structure as a table, the essential information is directly displayed in a 3D model of the production plant. The assignment of parts to manufacturing machines or to the production section can be recognized directly. If necessary, the worker is provided with the entire product structure in order to obtain information on the context of the product part. This is shown in the upper diagram of figure 1. A few interactions can also be used to retrieve parts lists or work instructions. In order to facilitate on-site access in the production plant, the operation is designed for mobile devices or touch interaction in order not to force the employee to go to a normal PC workstation.

2.3. Planning and virtual inspection

Simulation data from the product development can also show on the model of the manufacturing plant how the processes will look after the change. All the digital planning documents of the production plant and of the product to be produced can be used as required. One example of this is an ergonomic study at individual workstations, which are considered to be product-oriented, as they are determined by the sequence of the assembly and the placement of the components. This is done by relating information from real workstations to the simulation data of the virtual workstation. Information about the real counterpart of the manufacturing plant is displayed for the operator. The 3D model of the production plant also allows a virtual inspection of the new production.

2.4. Monitoring and control of a production plant

Within a production plant, many different IT systems are used. The ERP system distributes orders to machine groups. The MES distributes these orders to individual machines. In the event of an error, the employee needs access to all systems in order to be able to react quickly and in a manner appropriate to their needs: How important is the order (customer information, time bar from ERP)? What machines are affected and which machines still have capacity (MES)? Unfortunately, the systems often have different user interfaces and different access requirements. For this reason, the control desk bundles all information on production. For a quick understanding of the displayed data, the visualization is carried out on a realistic 3D model of the production line. The production managers always receive an up-to-date overview of all key figures and operating data. Problems and faults can be detected and eliminated earlier. In order to analyze the causes of problems, the data from the previous production processes can also be called up for comparison purposes.

3. Concept

The aim was to develop a concept for the consideration of the individual mental models in the application cases and to find a general procedure for new applications. On the other hand, the concept of a common technological basis for an integrated ELP demonstrator was developed.

3.1. Mental models

In psychology, mental models are individual explanatory approaches on the mode of action and the relationships of objects of reality. They are created bit by bit through experience and cognitive processing[6]. Mental models always simplify reality. Good mental models obtain the structure of the real scene (homomorphism) and contain all relevant aspects. However, some studies show that visual and even spatial models are common. Visualizations are representations of real data and thus models

that the user has to interpret. The interpretation should be easy for the users and they should have little room for misinterpretations. Therefore, the visualization model should be as similar as possible to the individual mental model of the users[7]. Discussions with production managers confirmed that many workers were imagining the production site as a space.

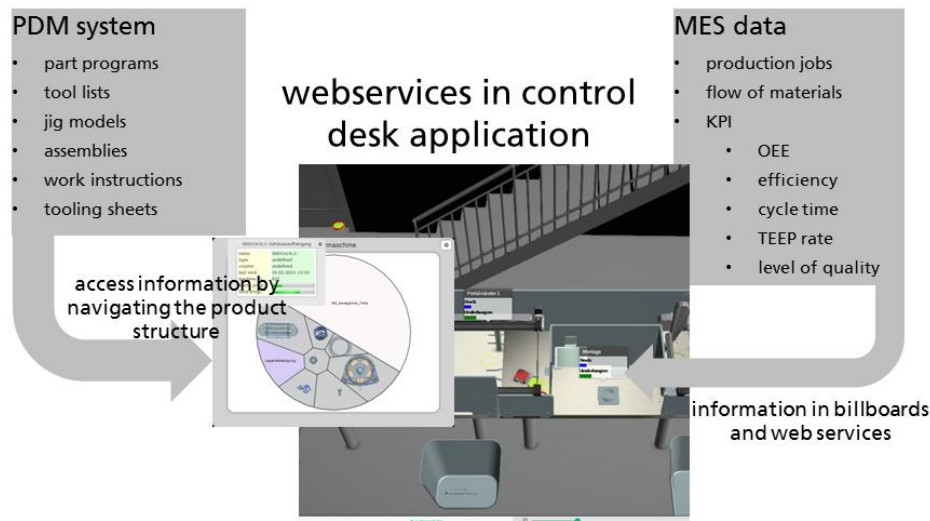


Figure 2. Information integration in control desk

For this reason, the 3D visualization of the manufacturing facility was chosen as closely as possible to the reality and the visual representation of the mental model in the imagination of the workers. Similar observations have also been made in product development. Here the 3D representation of the product and its components supports the understanding of the data better than abstract tree representations. The use of 3D models and the compilation in a real-world representation of the product or production hall is a successful approach for the use of mental models. However, there is no standard of a mental model for the implementation of control desks. In the development of the control desk, the expectation of the users must be taken into account. In addition, the mental models are also to take up the usual computer work processes of the users. Users work with a set of IT tools that they are accustomed to using. If an IT tool is to integrate user groups from different areas, it is necessary for each user to recognize his mental model in the tool. This allows the user to use the information quickly and effectively. Figure 2 shows the information that is aggregated in the two integrated systems. Information from the PDM system with production planning data and live data from the production process have to be shown in a single screen.

3.2. Preparatory work

In the preliminary work very different technologies (web-based application with Java and JavaScript and desktop application with Unity3D and C #) were used. At the start of the project it was, however, foreseeable that Unity3D will be able to create web-enabled applications in the future. For this reason, various possibilities of web-based integration were investigated. Both modules offer functionalities for a particular area of product creation. Plant@Hand3D offers the possibility to model the graphic representation and user interaction in a Unity3D development environment. This allows a factory model with short information and detail windows to be added. For the integration in Plant@Hand3D an extension for the display of web pages was developed and the modules for the MES and the PLM functionalities were implemented as websites. The second basic component - the PDM module - previously existed as a standalone Java application developed for multitouch tables[8]. For the integration, the application had to be web-enabled and almost completely rewritten in JavaScript. The access to the Siemens Teamcenter web services and to PLMXML files was taken over. The MES

functionalities were implemented in PHP and JavaScript. The allocation of the MES and PDM modules is controlled by an XML file, in which their web addresses are stored.

4. Integrated solution

After the application cases were defined, the technical concepts as well as the handling of the individual mental models were established, the refinement of the existing technological basis took place during the implementation phase. As a result, the modules were successfully integrated into one another in order to meet the requirements of the application.

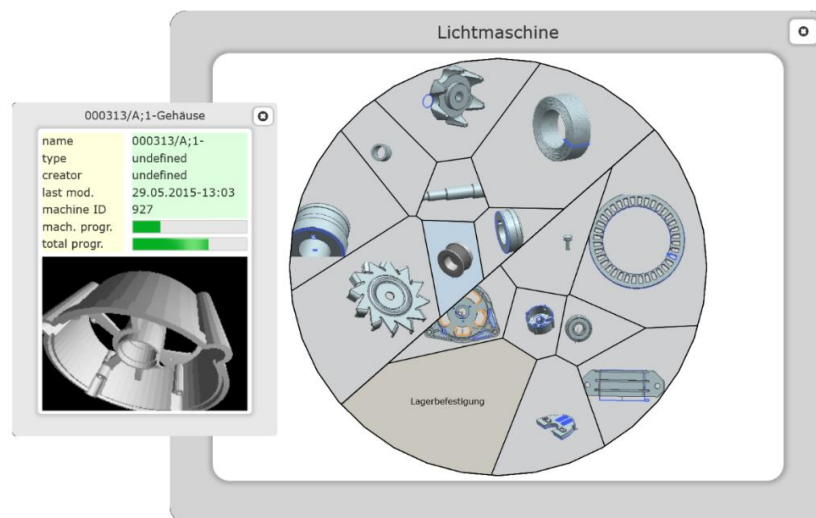


Figure 3. Representation of BOM in the PDM viewer

4.1. Components for control desks in production monitoring

All necessary elements for interaction with the control center (settings, zoom and navigation, selection of the data views and other context parameters) are displayed. The basic system is multitouch-capable and supports various end devices (PC, mobile phone, tablets) and platforms (web browser, Windows, Android, iOS). It thus achieves a very high range for various possible applications including mobile scenarios. A workflow has been created for the import of 3D models, which also allows highly detailed models to be simplified and used in the control room. An editor has been developed to reduce the development time and to simplify the customization process so that employees can also make changes without programming knowledge. The editor allows the parameterization of the individual machines to be identified in the various IT systems of the company. In this way, they can be connected to data from these systems.[9] Most data views are represented by short information and detail windows. For this purpose, some standard components were created for the visualizations. These can be used whenever both the data sources as well as the requirements of the customer permit it. As standard components, two types of line diagrams as well as a timeline and a tor- ding diagram were created to display KPI (Key Performance Indicators), machine data and status history. In addition, data views can also be directly affected by the 3D model (position, color, etc.) or as separate 3D objects in the production model. In order to visualize the flow of an order, additional 3D objects (arrows) are displayed between the machines to display the transaction data. The movement of these arrows can be written either as a planning task in the underlying planning systems or as a feedback for disturbances in the process.

4.2. Integration of the component PDM-Viewer

The PDM viewer is a single-page application for displaying product structures (see figure 3). First, it was developed as a standalone site with network access to a server of the Teamcenter PDM / PLM tool. From this server the application got the data of the product structure as well as of the individual assemblies and components using Web services and SOAP. With its integration within the framework of the MEF-ELP project, the application is no longer stand-alone, but is integrated into the Unity3D-based factory-control and monitoring program Plant@Hand3D via a web viewport. In the developed demonstrator, this variant retrieves its data both via Web Services / SOAP and a PLMXML file derived from the Teamcenter PLM system. This ensures the portability of the displayed information. This internally establishes a connection to the Siemens Teamcenter in order to be able to supply data and all structural elements, regardless of whether they are available on the network or locally. In addition, the connector controls the visualizations of the various product structures. The product structure is displayed using a Voronoi diagram. In this diagram, a cell represents a component or assembly, with the cell of an assembly being able to "go in" to open the underlying plane again in a subordinate Voronoi diagram.

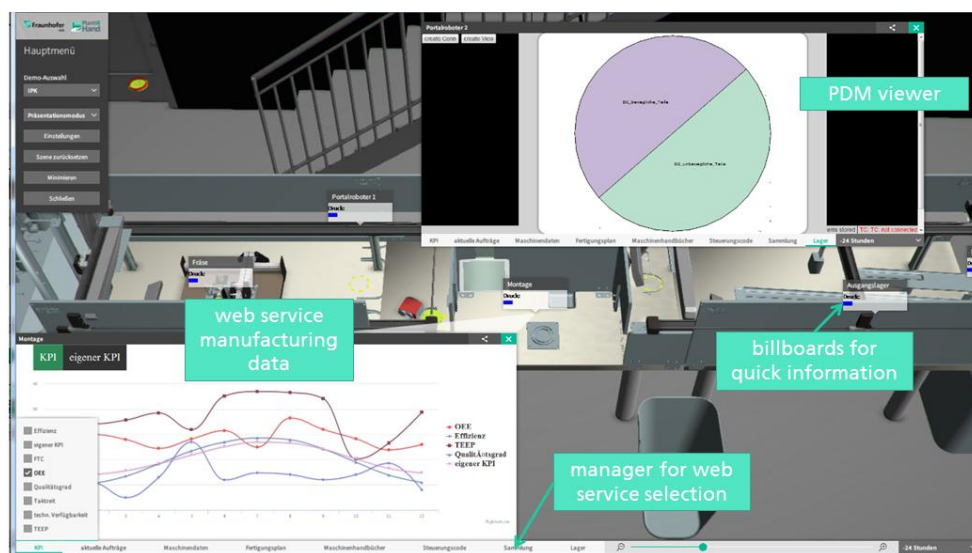


Figure 4. Integrated control desk demonstrator

Figure 4 shows the embedding of the module in the application cases. At first, a circular representation of the product structure appears in the Voronoidiagram[10]. The layers of the product structure are represented by the resolution levels in the tiles. As the top level, the entire system fills the circle completely. In the next detail stage the circle is subdivided into the subsystems. The figure shows an alternator, which is divided into the two subsystems rotor and stator. The next detail shows the components that make up the subsystems. Navigating to the respective detail levels is done by means of a pop-up menu, which, if pressed for a longer time, opens onto the Voronoi diagram. Another button opens an information dialog for the component. The existing metadata from the PDM system is displayed first. These are, for example, the item ID, the creator, and the last change. The current location of the component as well as the progress of the production can be displayed to a specific component of an order. The information is supplemented by a 3D view of the component, which can be rotated and enlarged with touch gestures. The lines of the information dialog are modularly defined in the program code and can be arbitrary extended or changed. In this way, this tool is easily adaptable to new applications. The new implementation has made it possible to easily integrate the PDM viewer as a component in the control desk, thus providing information from product planning.

4.3. Implementation of the component »MES-Webservices«

The machine data is processed and displayed in a highchart diagram in a javascript file. In addition, the navigation menu can be used to access a dashboard view, which is linked to another javascript file (see figure 4). The dashboard view provides an overview of machine parameters and compares them so that a quick overview can be obtained. In the current implementation, the data are obtained from a MONGO database, which is well suited for processing large amounts of data. The data can be simply integrated into the database from XML or JSON files and displayed in the dashboard.

4.4. Integration of different IT systems

The solution should make it possible to link the various data together, but not to duplicate data, but only to retrieve data from the data-carrying systems. For this purpose, a software architecture (see Fig. 5) has been developed which can collect and display data from different systems via different interfaces. All data can be displayed via different data views (managers). There are generally two stages. In the first stage, information is displayed as short information directly on the machine. If further details are required, a detail window can be opened from each brief information as a second stage. Data sources are generally accessed via REST or SOAP Web services. Direct access to a database is also possible. The frequency of the data queries can be scaled as required by the data record. The data context (time, type of data, etc.) can be set, and workflows in the IT systems can also be triggered (fault messages, rescheduling, etc.). Some companies use fully web-based IT systems that run the client application in the browser. For these cases a webrendering component was developed so that the contents of the web

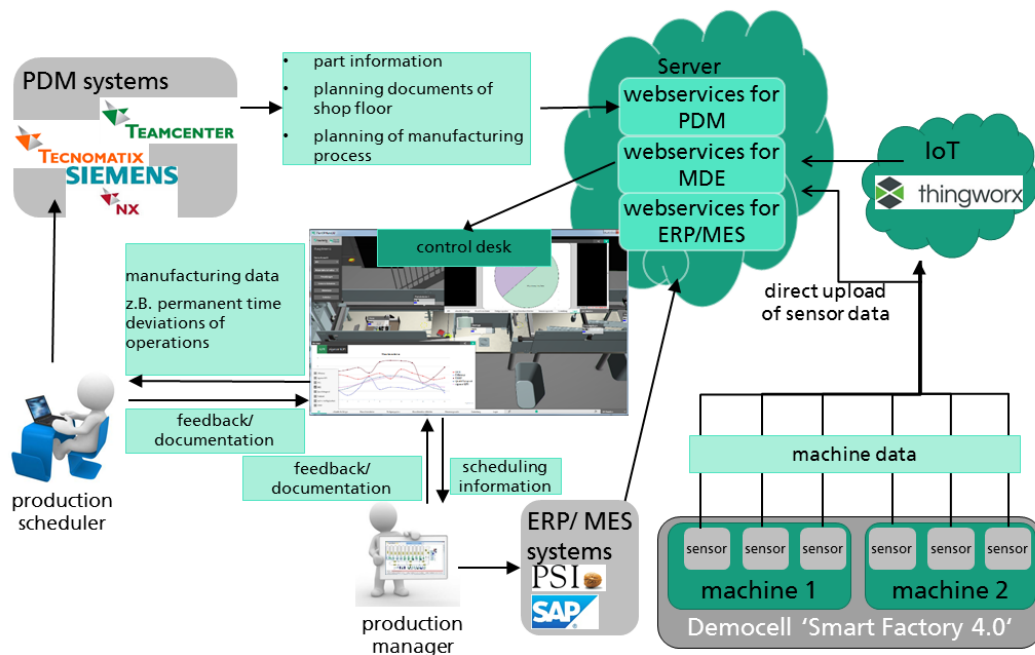


Figure 5. Architecture of IT system integration.

application can be executed directly in detail windows of the control desk. The integration of individual web pages or entire web applications is also completely possible without programming. A configuration file, which defines the URLs and additional parameters for defining the context, allows integration in a few minutes.

5. Evaluation

Within the scope of the project, the technical implementation of the individual components was divided between the partners. The integration of the components via a web rendering component or the

direct integration in the browser brought suitable results. In the course of the conversions, integration tests were carried out repeatedly with parts of the components and the respective state of the control room applications, so that a technical evaluation of the components was always present. As an expert evaluation, components and integrated demonstrators were repeatedly discussed with various industrial partners within the project. The most striking was the scenario of product development and production monitoring. At the moment, the companies still felt a small need for an increased interlocking of PDM and MES information, as the data situation in the companies is not yet sufficient. In order to present convincing examples for the visualization of information from the production, the control station was integrated and tested at the Fraunhofer IPK on the SmartFactory 4.0 demonstrator. The possibilities of the integrated control panel were presented to users in the PTK conference in 2017. In the demonstrator, the use-cases from chapter 2 are implemented to point out advantages for manufacturing. The cooperation with industrial partners in this field is important, since the interlinking of product development, production planning and production will increase in importance in the following years due to the growing importance of digitalization.

6. Conclusion

With this demonstrator of an integrated control desk, it is possible to apply and test various use cases of production processes. Information from two distinct processes of product creation were integrated in one tool. The visualization concept allows an intuitive navigation and access on relevant information. It is based on different mental models and the visual integration of data from the different areas supports the cooperation between engineers of the various work areas. The application provides a uniform interface for querying information from the product development and production planning and control systems, for monitoring data, and for initiating workflows. In particular, through the increase in information and the demands on the flexibility of work processes, an integrated and mobile-accessible presentation can achieve a better information supply. The solution is aimed at small and medium-sized companies in the mechanical and plant-engineering sector as well as suppliers for automotive manufacturers and aviation. Many of these companies are in global competition and have to switch to efficient, individualized production. Control desks help these companies with their information from the various IT systems more efficiently.

7. Acknowledgement

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